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Informal Report

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**Safety Test of an Improved Multihundred Watt FSA:
Launch Abort, Solid Propellant Fire**

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

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Informal Report
UC-71
Issued: July 1978

Safety Test of an Improved Multihundred Watt FSA: Launch Abort, Solid Propellant Fire

C. M. Seabourn

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SAFETY TEST OF AN IMPROVED MULTIHUNDRED WATT FSA:

LAUNCH ABORT, SOLID-PROPELLANT FIRE

by

C. M. Seabourn

ABSTRACT

This safety test consisted of exposing a simulant-fueled Improved Multihundred Watt Fuel Sphere Assembly, containing a Pt-3008 sphere holding the fuel simulant, to a single proximity fire of UTP-3001 solid rocket propellant for 10.5 min. The graphite outside shell sustained only minor abrasion damage. It was covered on one side with a heavy deposit of alumina from the fire mixed with silica from the test bed. The Pt-3008 shell had small amounts of carbon, alumina, and silica deposited on its surface but sustained no other damage. The Pt-3008 sphere was not breached, and therefore the fuel sphere assembly would not release fuel in a solid-propellant fire of a launch abort.

I. INTRODUCTION

As a part of the evaluation of Pt, 30 wt% Rh, 8 wt% W alloy (Pt-3008) developed by Oak Ridge National Laboratory as a containment material [postimpact containment shell (PICS)] for PuO_2 radioisotopic heat source fuel for the Improved Multihundred Watt heat source, a modified Multihundred Watt (MHW) Fuel Sphere Assembly (FSA) was exposed to a single proximity fire of UTP-3001 solid rocket propellant. The FSA is composed of the PICS containing the radioisotopic fuel placed inside a graphite impact shell (GIS) (Fig. 1). Replacing the standard iridium shell with Pt-3008 is desirable because Pt-3008 is less expensive and easier to fabricate. The test described in this report was carried out to see if a Pt-3008 PICS, which has a melting point some 400°C lower than that of iridium, inside a GIS could survive exposure to the intense heat of the solid-propellant fire.

Fig. 1.
As-received GIS and PICS for assembly as an FSA.

II. TEST DESCRIPTION

A. Test Specimen

A single FSA (PICS T-4 inside GIS S/N 936819-2) was used for the test. It was fabricated by Monsanto Research Corporation's Mound Facility (Miamisburg, Ohio) according to the standard MHW procedures, except that the PuO_2 fuel was replaced with a ThO_2 (thoria) simulant and the standard iridium shell was replaced with one made of Pt-3008. The data furnished with the FSA are given in the Appendix. The as-received specimen is shown in Figs. 1 and 2. The FSA was sent to us disassembled to facilitate our pretest inspections. There were no anomalies visible and none were detected by radiography; so the Pt-3008-clad thoria was inserted in the GIS, and the cap was screwed in place to form the FSA.

B. Propellant

The solid rocket propellant used for this test was a piece of UTP-3001 propellant 91.4 by 91.4 by 104.1 cm (36 by 36 by 41 in.). This is the propellant that is used in the Solid Rocket Motors of the Titan III, and it is quite similar to the propellant that will be used for the NASA Space Transportation System (STS) launch vehicle. The propellant was inhibited with Versamid 125*/Epon 815** epoxy on five sides and placed on a sand bed with the uninhibited 91.4-by 91.4-cm face vertical for the test. The propellant was inhibited on all surfaces not facing the FSA test item so that a maximum-duration fire would be obtained to simulate the period during which a large piece of a motor segment would burn.

C. Test Setup

The test setup is shown in Fig. 3. A tube furnace with a servo-operated door, for preheating the FSA in an air atmosphere, was suspended vertically from the metal stand. Below the furnace was an inclined metal trough that, upon initiation of the test, would carry the released FSA to the base of the un-

*General Mills Chemicals, Inc., Minneapolis, MN 55435.

**Shell Chemical Co., Houston, TX 77001.

Fig. 2.
As-received PICS showing one vent.

inhibited face of the propellant. The Transite* board seen in Fig. 3 leaning against the propellant face was used only before test initiation to prevent possible contact of the hot FSA with the propellant in the event of a premature FSA release. Immediately before test, this Transite board was removed. A hot-wire-initiated pyrotechnic igniter was affixed to the surface of the propellant. A bank of sand was built up behind the propellant to prevent tip-over of the propellant during the test.

Five W-26 Re/W-5 Re thermocouples encased in thoria tubes were placed near the ground level in front of the burn face of the propellant (Fig. 4). These thermocouples were connected to strip-chart recorders so that continuous records of temperature during the fire test could be obtained.

D. Test Operation

The furnace containing the FSA was heated to the 1020°C test preheat temperature in 1.5 h. This temperature was maintained by regulation of input power for 30 min to assure uniform temperature of the FSA. The furnace temperature was monitored by two thermocouples.

To initiate the fire test, the furnace door was activated, releasing the FSA. The FSA fell to the inclined metal trough (Fig. 3) and rolled down to the ground in front of the propellant, touching the

*Johns-Manville Corporation, Denver, CO 80217.

Fig. 3.
Test setup for propellant fire test.

propellant surface. On contact, the propellant ignited; however, to assure uniform ignition, the pyrotechnic igniter was initiated. Simultaneously, the metal structure holding the furnace was dragged ~5 m away from the ignited propellant by attached cables running to a pole (visible behind the furnace assembly in Fig. 5), then to a remotely operated winch. The propellant burned evenly and without incident for 10.5 min. High-speed movies were made of the burn.

Figure 5 shows the posttest condition of the test area. The arrow indicates the tested FSA. Figure 6 is a close-up view of the FSA showing the 1.5-cm-thick deposit of alumina and silica on the side of the FSA that had faced the burning propellant.

Temperatures measured by the thermocouples during the test are given in Table I. The maximum temperature experienced by the thermocouples and, therefore, by the FSA was 2060°C (T/C 1) at the beginning of the test. As the burning surface of the propellant receded from the FSA and the thermocouples, the observed temperature declined.

III. POSTTEST RESULT

Minor damage including some flaking of the graphite, was sustained by the outer surface of the FSA. Radiographs of several orientations of the FSA indicated that there was no detectable damage to the PICS. The cap of the GIS could not be unscrewed, so the GIS was cut open. Figures 7 and 8 are photos of the PICS showing a carbon image from the GIS (Fig. 7) and a ring-shaped deposit around a band where the GIS cap threads had been (Fig. 8). There was no observable damage to the vents (Fig. 8). From the information in Ref. 1, we concluded that the ring-shaped deposit was alumina from the propellant fire and silica from the sand test bed that had penetrated the GIS cap threads.

The PICS was dissected at a 30° angle to the weld. There was no observable damage to either the interior surface of the PICS or to the thorium fuel-simulant sphere (Fig. 9).

Photomicrographs of sections of the two hemispheres and welds are given in Figs. 10-12. The

Fig. 4.
Test setup showing thermocouple placement.

grain structure in all photos appears normal, thus the structure was apparently not altered by the fire test. There was no evidence of chemical reaction or eutectic formation by the carbon, alumina, or silica deposits on the PICS surfaces.

IV. CONCLUSIONS

A thorium-fueled, Pt-3008 PICS of an FSA did not fail when it was exposed to a 10.5-min UTP-3001 fire. There was no evidence of any but the most

Fig. 5.
Posttest view of the test site.

superficial changes in the condition of the FSA components after the fire. Thus, it appears that a Pt-3008 PICS of an FSA will survive a maximum-length single proximity UTP-3001 fire such as might occur in a launch abort of the Titan or STS launch vehicle. Probably, the Pt-3008 PICS inside a GIS could survive much larger single proximity fires without failure. It would not be expected to survive in the absence of the GIS, however, because the iridium cladding does not.¹

ACKNOWLEDGMENTS

I wish to thank N. K. Kernodle and the support personnel of WX-3 for their diligence and ingenuity in the fabrication of the test setup and the performance of this test. I also thank F. W. Schonfeld for the metallography for this test.

Fig. 6.
Posttest close-up of the FSA.

TABLE I
TEMPERATURE HISTORY OF PROPELLANT BURN^a

Time (min)	0.25 ^b	1	2	3	4	5	6	7	8	9	10	10.5
T/C ^c												
1	2060 ^d	1660	1638	1632	1610	1604	1552	1454	Failed	--	--	--
2	Failed	--	--	--	--	--	--	--	--	--	--	--
3	1827	1827	1827	1510	1499	1499	1499	1499	1499	1499	788	732
4	2038	1816	1232	1760	1427	1538	1538	1454	1316	982	816	704
5	2038	1982	1927	1454	1343	1260	1371	1427	954	482	288	221

^aPropellant was 91.4 by 91.4 by 104.1 cm.

^bTime of maximum temperature.

^cThermocouple locations:

1. 1.25 cm from base of propellant surface (near FSA), center.
2. 1.25 cm from base of propellant surface, center.
3. 1.25 cm from base of propellant surface, edge.
4. 30.5 cm from base of propellant surface, center.
5. 61 cm from base of propellant surface, center.

^dTemperatures in degrees Celsius.

Fig. 7.
Posttest view of the PICS showing graphite im-
print from the GIS.

Fig. 8.
Posttest view of the PICS showing the vent and
the ring deposit on the surface.

Fig. 9.
Interior of dissected PICS with thoria fuel
simulant sphere.

REFERENCE

1. E. C. Snow, "Safety Test No. S-6, Launch Pad Abort Sequential Test Phase II: Solid Propellant Fire," Los Alamos Scientific Laboratory report LA-6034-MS (August 1975).

(a)

(b)

Fig. 10.
Wall section of hemisphere A of the PICS at (a) 50X and (b) 100X.

(a)

(b)

Fig. 11.
Wall section of hemisphere B of the PICS at (a) 50X and (b) 100X.

(a)

(b)

Fig. 12.
Weld sections of the PICS at 50X. (a) hemisphere A and (b) hemisphere B.

APPENDIX

DATA PACKAGE FOR SIMULANT-FUELED FSA

MONSANTO RESEARCH CORPORATION

Inter-Office Correspondence

From	LOCATION	Hardware Fabrication	cc:	C. O. Brewer
	DATE	November 15, 1977		D. L. Prosser
	SUBJECT	<u>Pt-3008 Weld Shields and Decon Covers</u>		W. C. Wyder
	REFERENCE			File
TO	: E. W. Johnson			

Approximately thirty-six square inches of 5 mil Pt-3008 foil serialized E2X-4B-1 was received from Battelle-Columbus for use in fabricating weld shields and decon covers. This as-received material exhibited a wrought microstructure with a microhardness average (edge-center-edge) of DPH-430.

Eight weld shields and forty decon cover forming discs were blanked from this material. The forty discs were then heat treated (recrystallized) for one hour at 1100°C in vacuo. A metallographic sample indicated the discs were fully recrystallized, exhibited a grain size of ASTM-3, and a microhardness average of DPH-251. It should also be noted that no cracks or delaminations were observed in either the wrought or recrystallized metallographic samples.

The discs were then formed into decon covers and processed per MD-70161, Operation 6, (Forming of Iridium Decon Covers). However, the cleaning procedures deviated in that this hardware was acid cleaned in a 50:50 water-hydrochloric acid solution. The final production yield was 45% or 18 of 40 parts. Twenty were rejected for dome dye indications and two for dimensional anomalies. Although the material was fully recrystallized, it did not possess adequate ductility at room temperature.

The eight weld shields were processed per MD-70161, Operation No. 5, (Forming of Iridium Weld Shields). There were two process deviations however, one in cleaning and one in outgassing. The acid clean consisted of 50:50 water-hydrochloric acid solution and the hardware was heat treated (outgassed) for one hour at 1200°C in vacuo. Inadequate ductility at room temperature contributed to extreme difficulty in forming the weld shields on the roll fixture. The material work hardens rapidly and exhibits strong springback action.

Don A. Pawlak

DAP:eg

MONSANTO RESEARCH CORPORATION

From LOCATION : Hardware Fabrication

DATE : November 15, 1977

SUBJECT : Pt-3003 Hemishells

REFERENCE :

Inter-office Copy

cc: C. C. Brewer (w/o atts.)
C. L. Prosser (w/o atts.)
W. C. Wyder (w/o atts.)
File (w/att.)

TO : E. W. Johnson

This memo is written to document the reprocessing of four Pt-3003 hemishells serialized LCPT-26-1; 26-2; 26-3; and 26-4. These shells were supplied to MRC by ORNL for weld development and fabrication into impact test units.

Initially, the hemishells were solvent and acid cleaned; the latter being a 50:50 water-hydrochloric acid solution. However, this cleaning followed reweighing, repackaging, and identity verification. The hemishells were then heat treated (recrystallized) for one hour at 1050°C in vacuo. After recrystallizing, they were precharged and sized on 0.775-inch spherical radiused punch through a 1.602-inch diameter hardened steel die.

They were then sent to the Machine Shop for EDM vent holes in the poles and tapping of the equator to give a flat surface. A dye penetrant and completed gage lab inspection followed; however, the reprocessed hemishells were still out of hound but were pairable and required orientation marks. See Gage Report No. 107692 dated October 14, 1977.

After the orientation marks were grit blasted on the paired hemishells, they were again solvent and acid cleaned and heat treated (outgassed) for one hour at 1200°C in vacuo. They were then sent to Material Control and transferred to the weld group for subassembly along with four additional hemishells which were reprocessed in July of 1975. These shells were also solvent and acid cleaned and were serialized LCPT-22-4; 25-2; 25-4; and 27-3.

It should be noted at this point, however, that two hemishells (LCPT-26-1 and 26-4) were not acceptable (dye penetrant inspection) in accordance with Drawing No. 1-14944. Further examination indicated that hemishell rework was unfeasible, since wall thickness would be significantly reduced because of apparent indication depth. Subsequently, it was recommended that this paired set of hemishells be restricted to weld development.

1/2

E. W. Johnson

November 15, 1977

It is also significant to note that two of the 1975 reprocessed hemishells (LCPT-22-4 and 27-3) were also considered not acceptable following dye penetrant inspection. Subsequently, the appropriate dye inspection reports are attached.

Donald A. Pawlak

Donald A. Pawlak

DAP:eg
Attachments

MONSANTO RESEARCH CORPORATION*Inter-Office Correspondence*

From LOCATION : Weld Development and Fabrication
DATE : February 6, 1978
SUBJECT : Thoria Test Capsule Pt-3008, S/N T-4
REFERENCE :

cc: O. J. Bayes (w/o attach.)
J. L. Harrison (w/o attach.)
D. E. Friedline (w/attach.)
D. L. Prosser (w/o attach.)
File (w/attach.)

TO : E. W. Johnson

As part of the Improved MHW Heat Source Program, MF was requested to encapsulate three Pt-3008 Pu-238 heat sources and one Pt-3008 ThO₂ test capsule from four sets of Pt-3008 hardware. One complete set of hardware was designated for electron beam subassembly weld development with no destructive testing to be performed on the subassembly welds. This development set of hardware was used to fabricate Test Capsule Pt-3008 T-4.

The following is a record of assembly of that test capsule:

All welds were made using the MHW fixtures. The electron beam weld parameters were adjusted to accommodate the difference in the melting temperature of the platinum alloy versus iridium. The GTA weld was made per marked-up Operation Sheet MD-70161, No. 18, (attached).

Hardware: Platinum 3008 - Male - LCPT 26-1
Mate - LCPT 26-4
Gage Report - 107692.

Thoria Sphere - S/N 930 (outgassed 2 hours, 1000⁰F, at 10⁻⁵ torr).

The subassembled hardware was transferred to the "cold" MHW inert gas weld box. The hardware was assembled using MHW weld fixturing and welded per Operation Sheet MD-70161, No. 18. The PISA was welded in a helium atmosphere with the following impurities: <30 ppm O₂, <500 ppm N₂, and <60 ppm of H₂O.

NOTE: Impurity measurements were made before the start of the weld due to analyzer interference by the 75 He/25 Ar torch gas.

E. W. Johnson

February 6, 1978

Weld Inspections: Visual - good.
Weld Bead Width - 0.085" to 0.110".
Helium Leak - $<10 \times 10^{-10}$ cc/sec He.
Dye Check - No dye indications using "Tracer Tech",
150 Dye.

The decontamination covers were activated. A Graphite Impact Shell (GIS),
S/N 936819-2, is included for shipment to LASL.

Charles O. Brewer
C. O. Brewer

COB:eg
Attachment

2/2

MONSANTO RESEARCH CORPORATION
MOUND LABORATORY

MULTI-100
OPERATION SHEET

PROGRAM MULTI-HUNDRED WATT HEAT SOURCE		SHEET 1 of 1	MANUAL NUMBER MD-70161	OPERATION 18
AUTHORIZATION <i>[Signature]</i>	CLASSIFICATION Unclassified	EFFECTIVITY 2-20-74	ECNISI INCORPORATED M7-C	

OPERATION TITLE
PISA TIG WELD SCHEDULE

MILLER WELDING MACHINE MODEL SR-200-A-LA(S) AIRCRAFTER

ASSEMBLY NAME MIW IRIIDIUM SPHERE
 FIXTURE TYPE OR DRAWING NUMBER MIW Servo-Tek Rotary Fixture
 ROTATIONAL CONTROL TYPE Servo-Tek (370 Setting Ref.)
 ACTUAL TIME PER REV. 10 SEC. RUNNING START ☐ DELAYED START ☒
 TIME OF DELAY .2 SEC. TORCH TYPE Linde GAS CUP SIZE 4 TORCH GAS 75 He 25 Ar 70 (CG)
 FLOW 25-10 C.F.H. BOX GAS He ELECTRODE TYPE 23 Th DIAMETER 1/8"
 ARC GAP 0.040" POINT SHAPE Special D.C.S.P. WELDING CURRENT 75-75 AMPERES
 RECORDER ☐ METER ☒ WATER PRESSURE TO THE HEAD HOLD DOWN 12 lbs.

15 PSI on left gage
(Up)
17 PSI on right gage
(Down)

ELECTROSCOPE

TIMER CONTROL PANEL
Weld time - Durant counter 610

ARC OSCILLATOR SETTINGS

Position 6150 This gives a dwell time of 75 Msec. (CG)
 Amplitude 2035
 Left Dwell 8 Model 80A Celeasco
 Speed 0 Power supply - S/N
 Right Dwell 9 6702-107, Magnet-S/N 6703-4300

WELDING CURRENT CONTROLS

JOINT TORCH ANGLE

ELECTRODE POINT SHAPE

Use Additional Sheets if Needed.

LEAK TEST REPORT

Name and Model Number of Instrument M5-12
 Standard S.N. 12559 Standard Value 4.58×10^{-8} cc/min h
 Minimum Detectable Leak Background

TEST TECHNIQUE:

- ☐ Item pressurized at _____ psig for _____ under Helium.
☒ Helium contained in item. ☐ Item tested in Helium hood.
☐ 'Sniffer' probe technique. ☐ Helium spray technique.
☐ Other _____

ITEM DESCRIPTION:

Platinum 3008 (LCPT-26-4)
thoria encapsulation. (LCPT-26-1)

TEST RESULTS:

Item identification _____	Item identification _____
Background <u>2.1×10^{-10}</u>	Background _____
Standard <u>4.58×10^{-8} cc/min</u>	Standard _____
Item <u>2.1×10^{-10}</u>	Item _____
Leak Rate <u>2.1×10^{-10} cc/min/h</u>	Leak Rate _____
Item identification _____	Item identification _____
Background _____	Background _____
Standard _____	Standard _____
Item _____	Item _____
Leak Rate _____	Leak Rate _____

COMMENTS: _____

By: Irwin Rodet Date: 12-9-77

MRC-ML-3561 (11-76)

Date 10-4-77

Distribution:
W. C. Wyder
File:

FLUORESCENT DYE PENETRANT REPORT

Item: PLATINUM HEMISHELLS

LCPT- 26-1 = Not acceptable in accordance with DWG. No. 1-14944
Cracks 0.065" in from Eq. 0.280" long, (outer surface).

LCPT- 26-4 = Not acceptable in accordance with DWG. No 1-14944.
Two cracks on outer surface 0.015" in length, near
dome area.

Listed below are the hemishells that are acceptable in accordance
with DWG, No. 1-14944.

LCPT- 26-2 = Acceptable.

LCPT- 26-3 = Acceptable.

Inspected in accordance with ASTM E-165
Procedure A-2

Inspected by *Ernie D. Dobb*

Date: 10-27-77

Distribution:
D. A. Pawlak
File:

FLUORESCENT DYE PENETRANT REPORT

Items: DECON COVERS (IRIDIUM)

PT-3008 Material

S/N- E2X-4B-1 20 pcs. All acceptable on dye penetrant inspection.

Inspected in accordance with ASTM E-165
Procedure A-2

Inspected by:

James A. Strickter

Date 10- -77

Distribut i:

N. D. Hignite
W. C. Wyder ✓
File:

FLUORESCENT DYE PENETRANT REPORT

Item: DECON COVERS

Material; PT-3008
S/N-E2X-4B-1

Accept= 20
Reject= 20
Total 40 pcs.

The 20.pcs rejected are for cracks in the dome area.

Inspected in accordance with ASTM-E-165
Procedure A-2

Inspected by *Eric W. Doherty*

Date 10-4-77

Distribution:

W. Wyder

File:

FLUORESCENT DYE PENETRANT REPORT

Item: PLATINUM HEMISHELLS

LCPT- 26-1 = Not acceptable in accordance with DWG. No. 1-14944
Cracks 0.065" in from Eq. 0.280" long, (outer surface).

LCPT- 26-4 = Not acceptable in accordance with DWG. No 1-14944.
Two cracks on outer surface 0.015" in length, near
dome area.

Listed below are the hemishells that are acceptable in accordance
with DWG, No. 1-14944.

LCPT- 26-2 = Acceptable.

LCPT- 26-3 = Acceptable.

Inspected in accordance with ASTM E-165
Procedure A-2

Inspected by *James D. Smith*

RECEIVING REPORT

ORDER NO. NONE

INVOICE TERMS
From Receipt of Goods or
Invoice - whichever is later.

REQUIRED SHIPPING DATE

DATE OF ORDER

BUYER:

THIS ORDER NUMBER MUST APPEAR ON
OUTSIDE OF EACH PACKAGE AND ON
ALL SHIPPING PAPERS AND INVOICES.

TO

**MONSANTO RESERCH CORP
MIAMSBURG OHIO**

SHIP TO:
University of California
Los Alamos Scientific Laboratory
Receiving Dept.
P. O. Box 990
Los Alamos, New Mexico 87545

For Order Information phone 505-667.

F.O.B.		SHIP VIA		SHIP FROM	
ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	EXTENSION
	SIMULATED RUEL SPHERE ASSEMBLY CONSISTING OF: 1 each GRAPHITE SHELL S/M936819-2 1 each Thoria Sphere 232/19 S/M930 1 each Pt. 3008 Shell 60.95g Pt.	1	each		
	RADIOACTIVE MATERIAL				
	D.R. 63046 by S.E. Bering				

AO SP-2, 3, 4, 12		REQUESTER		FRT BILL		RECEIVING REPORT RR 60073-e	
CARRIER FedExp 78157563	ACCOUNT	PROGRAM	LOC.	SOR.	EXP.	PAREN.	JOB ORDER
MATL. RECD. 2/9/78	CKD.	REC. CLERK Lopez	PACKING LIST/DATE		SPECIAL INSPECTION		
GROUP CMB5	SITE TA3	BUILDING 229	ROOM 2144	FOR Brozisz		AO-1 USE ONLY	

FORM 588 REV. 6/73

U.S. Government Printing Office-1977-781-260/109

Date 6-11-75

Distribution:

W. C. Wyder

File:

FLUORESCENT DYE PENETRANT REPORT

Item PLATINUM RHODIUM

HEMISPHERES

The following parts are acceptable on dye penetrant inspection.

LCPT- 22-2 LCPT- 23-3 LCPT- 25-4

LCPT- 22-3 LCPT- 23-4

LCPT- 23-1 LCPT- 24-2

LCPT- 23-2 LCPT- 25-2

The following hemispheres are not acceptable in accordance with
DWG. No. 1-14944.

LCPT-22-4 = (1) crack 0.020" long inside of part at dome area.

LCPT-24-3 = (1) Gouge at inner edge , 0.015"x0.030".

LCPT-24-4 = (1) indication area 0.005"x 0.005", located inside 0.250"
from edge. (porous area).

(1) Crack or tear in metal 0.002"x 0.030", on outer surface
0.600" from edge.

LCPT-27-2 = (1) Crack 0.004", (outside of part) at dome. area.

LCPT-27-3 = (1) Rough surface located at inner edge, 0.005" x 0.010".

Inspected in accordance with ASTM E-165
Procedure A-2

Inspected by *W. C. Wyder*